

ON OLIVINE-DIABASE FROM DAVIDSON COUNTY, NORTH CAROLINA.^a

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Introduction.—The terms “basalt” and “diabase” have been employed with varying significance in this country and abroad. By diabase, as used herein, is meant a basic igneous rock, composed predominantly of plagioclase and augite, having ophitic texture, and occurring in dikes or intrusive sheets. Where olivine is present as an essential constituent the rock is termed an olivine-diabase.

Olivine-diabase, though by no means a rare rock, has not the wide distribution of the olivine-free members of the diabase family. In the United States it has been described, in more or less detail, as occurring at St. George (5),^b Kennebunkport (12), Addison Point and Vinalhaven (18), Maine; in the Lake Champlain region (13); at Deerfield (7) and Cape Ann (22), Massachusetts; among the Thousand Islands, in the St. Lawrence River (24); in the Palisades of the Hudson, in New Jersey (16, 17); in Culpeper (1), Floyd (27), and Pittsylvania (28) counties, and near Harrisonburg (4), Virginia; in Rowan (14) and Davidson (21) counties, North Carolina; in Lee County, near Gold Hill, Alabama (2); in the Diablo and Van Horn mountains of Texas (19); near Pilot Knob and Iron Mountain, Missouri (10); in Minnehaha County, South Dakota (3); at Pigeon Point, Cook County, Minnesota (6), and a number of localities near Brule River and Duluth (26); in the Marquette iron-bearing district of Michigan (25) and the Penokee series of Michigan and Wisconsin (11); in California, near San Luis (8) and in the San Francisco peninsula (15); in Kittitas County, Washington (23); and in Alaska near

^a The data for the present paper are taken largely from a report, by the writer, on the Cid mining district of Davidson County, North Carolina, which is now in press and will appear as Bulletin No. 21 of the North Carolina Geological Survey. For this privilege the author is indebted to the courtesy of Dr. Joseph Hyde Pratt, the state geologist.

^b The numbers in parentheses refer to the bibliography at the end of the article.

Stepovak Bay (20).^a The majority of these descriptions are very brief; some include petrographic details, but very few contain such important essentials as chemical or mineralogical composition. Most of the occurrences, too, represent rocks more or less changed by alteration.

In view of the above considerations, a detailed quantitative description of an olivine-diorite of exceptional freshness and unusual richness in olivine is herein given. The material is represented in the U. S. National Museum collections by deposit No. 77422.

Field occurrence.—Olivine-diorite occurs in Davidson County, North Carolina, in the form of dikes which cut a series of ancient volcanic rocks. This series includes slate, acid tuffs and breccias, rhyolite, dacite, andesitic tuffs and breccias, andesite, and dikes of gabbro and diorite, and is a part of a broad band of volcano-sedimentary rocks, called the "Carolina slate belt," which crosses the State in a northeast-southwest direction, forming an important part of the Piedmont Plateau. The dikes are uniformly, though not abundantly, distributed, and show upon the surface as narrow lines of rounded, yellowish boulders, locally called "nigger-heads." They vary in size from a few feet in width and a few yards in length to a hundred feet in width and over a mile in length. The majority conform to the former rather than to the latter dimensions. In trend they also vary, but the more common directions are included between N. 30° E. and N. 30° W.

The olivine-diorite is doubtless of Triassic age, for dike rocks of similar character have a widespread occurrence throughout the Piedmont Plateau, and in many places may be traced into areas of Triassic sandstone.

Megascopic description.—The olivine-diorite is a massive, fine-grained, dark-blue rock, with a faint purplish tinge and a more or less waxy luster. To the unaided eye it appears a closely knit aggregate of dark-colored minerals, showing numerous small crystal faces. With the hand lens it is possible to recognize occasional striated feldspars, and to distinguish from these the darker-colored ferromagnesian constituents. The augite and olivine, however, can not be differentiated; this is notable in view of the fact that the latter mineral comprises nearly one-fifth of the rock.

Microscopic description.—The microscope reveals the following minerals, named in the probable order of their formation: Iron ore, olivine, plagioclase, and augite. (See pl. 37.)

^a Many of the rocks along the Atlantic coast formerly described as "trap," under present usage would be termed olivine-diorite; but an attempt to differentiate these would involve too long a discussion for the present purpose.

The feldspar is basic labradorite, possibly running into bytownite, and makes up about 45 per cent of the rock. It occurs in long, slender laths of subhedral habit. The albite twinning is universal, in combination with which is occasionally found a Carlsbad twin. Zonary structure is not pronounced. Inclusions consist of small particles of iron ore and rare shreds of biotite. The alteration of the feldspars is insignificant.

Augite, the most common ferromagnesian constituent, forming about 35 per cent of the rock, is pale green in color and nonpleochroic. It rarely shows crystal outline, but surrounds and incloses the feldspars, forming a matrix in which they are arranged at random. Iron ore occurs as inclusions, and the alteration product, of which there is little, is a pale green, scaly mineral, probably antigorite.

Olivine is present to the extent of about 17 per cent, and forms rounded crystals or grains of a very pale color. It includes particles of iron ore, and is partly changed to talc instead of serpentine, the more common alteration product of olivine. This mode of decomposition differs from the more usual form in that the change is not confined to the cracks of the mineral, but proceeds independently of these, often beginning within the crystal, and is not necessarily accompanied by the segregation of iron ores. The formation of talc from olivine is very unusual in an olivine-dabase, though among the Appalachian peridotites this mode of alteration, termed "steatitization," is stated to be comparable to serpentinization.^a

The iron ores are abundantly scattered through the rock, but prefer the company of the ferromagnesian minerals, particularly olivine. They occur in both grains and specks, and rarely show good crystal outline.

Texture.—The diabase forms an excellent example of the ophitic texture; that is, the feldspars are long, slender laths, arranged at random, and around these the augite is molded. The olivine mostly holds its own form against that of the plagioclase, but in some cases it includes, or partly includes, a feldspar lath. Thus it appears that the olivine in part crystallized previous to the feldspars, and in part the crystallization was simultaneous.

Mineral composition or mode.—The percentage of the actual mineral components was determined according to the Rosiwal method,^b by measuring with a micrometer the diameters of each crystal in lines across the thin section. The feldspar, augite, olivine,

^a J. H. Pratt and J. V. Lewis, *Corundum and the peridotites of western North Carolina*, N. C. Geol. Survey, vol. 1, 1905, pp. 121-123.

^b Rosiwal, *Vehr. Wien Geol. Reichs-Anst.*, vol. 32, 1898, p. 143 ff. See Cross, Iddings, Pirsson, *Washington, The quantitative classification of igneous rocks*, 1903, p. 204.

and magnetite could be accurately determined. No allowance was made for the small amount of alteration products present, for the magnetite being in part ilmenite, nor for a slight proportion of orthoclase doubtless associated with the plagioclase. The error arising from these sources was not considered sufficient to materially affect the result. The average size of grain was found to be 0.17 mm. and a total distance of 32.30 mm. was traversed, with the results given in the table:

Mineral composition or mode of olivine-d diabase.

Ratio of volumes.	Specific gravity.	Ratio of weights.	Mode.
1,655×	2.72	=4,502	=45.6 per cent plagioclase.
1,025×	3.4	=3,485	=35.3 per cent augite.
515×	3.34	=1,720	=17.4 per cent olivine.
35×	5	=175	=1.8 per cent magnetite.

By giving definite values to the mineral components, the chemical composition may be calculated from the mode. The plagioclase was estimated to be Ab_1An_3 ; to the augite was assigned the composition obtained for this mineral in an olivine-hypersthene diabase from Culpeper County, Virginia;^a for olivine, an analysis of this mineral from Montarville,^b Montreal, Canada, was taken. Magnetite was given its theoretical value. The results are shown in the following table:

Chemical composition of olivine-d diabase calculated from its mode.

	Feldspar.	Augite.	Olivine.	Magnetite.	Total.
SiO ₂	22.5	17.4	6.5	.....	46.4
Al ₂ O ₃	14.9	3.2	.....	.....	18.1
Fe ₂ O ₃.....	.....	.1	.....	1.2	1.3
FeO.....	.....	3.2	3.9	.....	7.7
MgO.....	.....	5.2	6.9	.....	12.1
CaO.....	7.0	5.8	.....	.....	12.8
Na ₂ O.....	1.3	.2	.....	.....	1.5
K ₂ O.....	.....	.1	.....	.....	.1
Total.....	45.7	35.2	17.3	1.8	100.0

Chemical composition.—The chemical analysis of the olivine-d diabase is given in column I of the following table. Columns II and III include the average compositions of olivine-d diabase and normal diabase as obtained from a large number of reliable analyses: In parentheses accompanying these two columns are shown the limits for each component. The analyses of two related rocks are added for comparison in columns IV and V.

^a Bull. Geol. Soc. Am., vol. 2, 1891, p. 344.

^b Amer. Jour. Sci., vol. 29, 1860, p. 283.

Analyses of olivine-diabase and related rocks.

	I.	II.		III.		IV.	V.
		Average.	Extremes.	Average.	Extremes.		
SiO ₂	47.66	50.14	(52.7-39.64)	51.34	(58.28-46.52)	46.63	45.73
Al ₂ O ₃	19.24	14.35	(18.86-10.62)	15.53	(21.79-10.60)	14.40	13.48
Fe ₂ O ₃	1.83	5.60	(10.43- 1.11)	4.12	(12.36- .15)	2.85	11.60
FeO.....	8.67	5.66	(9.66- 2.85)	7.20	(13.62- 2.71)	8.06	not det.
MgO.....	10.79	7.56	(13.05- 5.09)	6.13	(12.73- 1.30)	7.25	15.40
CaO.....	9.91	10.83	(11.94- 9.68)	8.98	(14.70- 2.86)	9.28	9.92
Na ₂ O.....	1.14	2.93	(5.95- 1.17)	2.87	(4.74- .97)	2.47	3.24
K ₂ O.....	.26	.93	(3.09- .23)	1.09	(3.75- .04)	.70	.47
H ₂ O.....	.06	1.14	(2.56- .14)	1.46	(5.58- .00)	etc.	.94
Total.....	99.56						100.78

I. Chemical analysis of olivine-diabase from near Fairmont, Davidson County, North Carolina. A. S. Wheeler, analyst.

II. Average and extreme values of 9 analyses of olivine-diabase appearing in Washington's Tables. Includes all analyses of olivine-diabase marked "superior." From chemical analyses of igneous rocks published from 1884 to 1900, U. S. Geol. Survey, Prof. Paper No. 14, 1903; and the superior analyses of igneous rocks from Roth's Tabellen, 1869 to 1884, U. S. Geol. Survey, Prof. Paper No. 28, 1904.

III. Average and extreme values of 62 analyses of diabase appearing in Washington's Tables. Includes all "superior" analyses of normal diabase.

IV. Chemical analysis of diabase (augerose), Mount Asectney, Vermont. W. E. Hillebrand, analyst. From U. S. Geol. Survey, Bull. No. 148, 1897, p. 70.

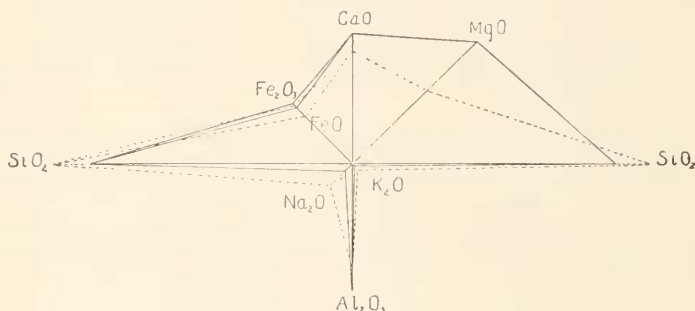
V. Chemical analysis of olivine-diabase from Pittsylvania County, Virginia. T. L. Watson, analyst. From Amer. Geol., vol. 22, 1898, p. 87.

Discussion of the chemical composition.—Comparing first column I of the above table with the results obtained in the preceding table, it will be seen that the composition as derived by microscopic determination is in pretty fair accord with the more exact results of the chemical analysis. The chief points of difference lie in the rather high amounts of magnesia and lime present in the former. This discrepancy must be attributed chiefly to the values assumed for the variable components, augite and olivine; that the first was too calcic and the second too high in magnesia. The microscopic analysis is sufficiently accurate to be of value in classifying the rock, inasmuch as its position in the quantitative system is the same, whether calculated from the chemical or microscopic analysis.

Turning now to a comparison of the chemical analysis of the rock described (I) with the average composition of olivine-diabase (II) and normal diabase (III), the following features appear regarding the Davidson County olivine-diabase: Low in silica; high in alumina; ferric iron low; ferrous iron fairly high; magnesia high; lime a little high; alkalis a bit low. The rock is consequently extremely basic, due chiefly to the large amount of olivine present. The high percentage of alumina indicates a very aluminous augite, low in calcium. The olivine is judged to be fairly high in ferrous iron. By a comparison with the extreme values for each component given in parentheses the relations of the rock under discussion are still more accurately brought out, particularly in regard to those components, i. e., alumina and magnesia, which approach most closely the extremes.

The accompanying figure represents graphically the relationships brought out by columns I and III of the preceding table.

A few words may be added in regard to the method here used of comparing the composition of a described rock with composite analyses. Usually it is customary, in quoting an analysis, to include for comparison several analyses of related rocks. The analyses selected are apt to be those which correspond most closely with the rock described. Occasionally, however, a dissimilar analysis may be inserted, or a series of analyses ranging from a close approximation to an extreme of the same type; but in any case the chief feature brought out is whether the individual occurrence is like or unlike other individual occurrences, and unless one has a sufficient working knowledge of analyses to visualize an average the exact quantitative relation of a member of a type to that type does not completely



GRAPHIC REPRESENTATION OF THE CONSTITUENTS OF THE OLIVINE-DIABASE DESCRIBED (SOLID LINES) AND THE AVERAGE NORMAL DIABASE (DASH LINES).

appear. Now that Washington's admirable collections of rock analyses are available, and in these the reliable analyses are grouped, it is a matter of little difficulty to determine, by averaging, the composition of any rock type desired, and in doing this to note the extreme values, both low and high, for each component. A column thus obtained, including the average and extreme values for each component, serves well in determining the significance of each constituent, and the analysis as a whole, of any rock under discussion. The use of extreme values must be made with caution, however, as such values are more likely than normal values to be the result of some error in analysis.

Certain differences between a composite olivine-diabase and a composite normal diabase may be observed in columns II and III, but a discussion of these does not come within the province of the present paper.

Classification in the quantitative system.^a—From the chemical analysis of the rock previously given, its position in the quantitative system may be determined by calculation of the norm, as follows:

Calculation of the norm of kedabekase (olivine-diabase).

	Analysis.	Molecular ratio.	Or.	Ab.	An.	Mg.	Di.	Ol.	Hy.
SiO ₂	47.66	0.794	18	108	334	.....	20	55	259
Al ₂ O ₃	19.24	.188	3	18	167	.....	.....	.....	.....
Fe ₂ O ₃	1.83	.011	.....	.....	.....	11	.....	.....	.....
FeO.....	8.67	.121	.....	.....	.....	11	3	32	75
MgO.....	10.79	.269	.....	.....	.....	.....	7	78	184
CaO.....	9.91	.177	.....	.....	167	.....	10	.....	.....
Na ₂ O.....	1.14	.018	.....	18	.....	.....	.....	.....	.....
K ₂ O.....	.26	.003	3	.....	.....	.....	.....	.....	.....
H ₂ O.....	.06	.....	.....	.....	.....	.....	.....	.....	.....

Or.....	1.67	} 57.53	} 41.89	} 41.89	} 57.53	} 21	} 167	} .12	} 5	} 5	} .06	} 99.48	} Class, $\frac{Sal}{Fem} = \frac{57.53}{41.89} = 1.3 = III$, salfemane.	} Order, $\frac{Q}{F} = \frac{0}{57.53} = 0 = \text{perfelic} = 5$, gallare.	} Rang, $\frac{K_2O + Na_2O}{CaO} = \frac{21}{167} = .12 = \text{percalcic} = 5$, kedabekase.	} Subrang, not needed.
Ab.....	9.43															
An.....	46.43															
Di.....	2.26															
Hy.....	28.30															
Ol.....	8.78															
Mg.....	2.55															
H ₂ O.....	.06															
	99.48															

Weathering.—The olivine-diabase is not very susceptible to superficial alteration. Where cut by joint planes, however, it forms concentrically weathered boulders with a yellow or rust-colored exterior. This coating of clay-like material stained with iron oxide is only a very small fraction of an inch in thickness, and beneath is revealed the fresh rock. The soil resulting from the complete decomposition of these boulders is a rust-colored clay with very little grit.

LITERATURE ON OLIVINE-DIABASE OCCURRING IN THE UNITED STATES.^b

1. CAMPBELL, H. D., and BROWN, W. G. Composition of certain igneous rocks of Virginia.
 Bull. Geol. Soc. Am., vol. 2, 1891, pp. 339-347.
 Gives the chemical composition of an olivine-hypersthene diabase from Culpeper County, Virginia.

^a As proposed by Cross, Iddings, Pirsson, and Washington in 1903. For explanation of this method of classification the reader is referred to their book, *The Quantitative Classification of Igneous Rocks*.

^b This bibliography is not intended to be exhaustive. It contains, however, the most important articles, in which are included petrographic or chemical descriptions of olivine-diabase. There are references to no less than several hundred articles on "trap rock" in the so-called Newark series alone (see I. C. Russell, *The Newark System*, Bull. No. 85, U. S. Geol. Survey, 1892), and many of these are what would now be termed olivine-diabases.

2. CLEMENTS, J. M. Notes on the microscopic character of certain rocks from north-east Alabama.
Ala. Geol. Survey, Bull. No. 5, 1896, pp. 133-176.
Gives a brief description of an olivine-diabase from Gold Hill in Lee County.
3. CULVER, G. E., and HOBBS, W. H. On a new occurrence of olivine-diabase in Minnehaha County, South Dakota.
Trans. Wisc. Acad., vol. 8, 1892, p. 206.
Describes briefly a somewhat altered olivine-diabase.
4. DARTON, N. H., and DILLER, J. S. Occurrence of basalt dikes in the upper Paleozoic of Appalachian Virginia.
Amer. Jour. Sci., vol. 39, 1890, p. 269.
Mentions the occurrence of an olivine-diabase near Harrisonburg.
5. DICKERMAN, Q. E., and WADSWORTH, M. E. An olivine-bearing diabase from St. George, Maine.
Boston Soc. Nat. Hist., vol. 23, p. 28.
Very brief description.
6. DILLER, J. S. The educational series of rock specimens collected and distributed by the United States Geological Survey.
U. S. Geol. Survey, Bull. No. 150, 1898, pp. 274-278.
Includes a description, with chemical analysis, of an olivine-diabase, formerly described as an olivine-gabbro, from Pigeon Point, Cook County, Minnesota. Contains about 10 per cent olivine.
7. EMERSON, B. K. The Deerfield dyke and its minerals.
Amer. Jour. Sci., vol. 24, 1882, pp. 195-202; 270-278; 349-359.
Olivine is uniformly present.
8. FAIRBANKS, H. W. San Luis Folio, California.
U. S. Geol. Survey, Geol. Atlas of U. S., folio No. 101, 1904, p. 7.
Describes diabase exceptionally rich in olivine; this is often the most important constituent. Rock is generally much decomposed.
9. HAWES, G. W. On a group of dissimilar eruptive rocks in Campton, New Hampshire.
Amer. Jour. Sci., vol. 17, 1879, pp. 147-151.
Includes brief description of an "olivine-diabase." This rock is now regarded (Rosenbusch) as a camptonite.
10. HAWORTH, E. A contribution to the Archæan geology of Missouri.
Amer. Geol., vol. 1, 1886, pp. 280-363.
Dikes of olivine-diabase of Archæan age occur in the vicinity of Pilot Knob and Iron Mountain. Rock is very fresh.
11. IRVING, R. D., and VAN HISE, C. R. The Penokee Iron-bearing series of Michigan and Wisconsin.
U. S. Geol. Survey, Mon. 19, 1892, pp. 350-354.
Olivine is present in comparatively few of the diabases. In one case is very abundant.
12. KEMP, J. F. Trap dikes near Kennebunkport, Maine.
Amer. Geol., vol. 5, 1890, p. 129.
Describes briefly an olivine-diabase.
13. KEMP, J. F., and MARSTERS, V. F. The trap dikes of the Lake Champlain region.
U. S. Geol. Survey, Bull. No. 107, 1893, pp. 28-29.
Olivine occurs in a few dikes, and what may be an alteration product of it is present in others.
14. LANEY, F. B. The Gold Hill Mining District of North Carolina.
Bull. N. C. Geol. Survey (in press).
Describes olivine-diabase from Rowan County.
15. LAWSON, A. C. Sketch of the geology of the San Francisco peninsula.
U. S. Geol. Survey, 15th Ann. Rept., 1895, pp. 405-476.
Describes briefly typical olivine-diabase which probably represents small dikes.

16. LEWIS, J. V. Petrography of the Newark igneous rocks of New Jersey.
Ann. Rept. Geol. Sur. N. J., 1907, pp. 97-167.
Includes a detailed description of olivine-d diabase from the Palisades in New Jersey, with analyses, diagrams, photomicrographs, etc.
17. ——— The Palisade diabase of New Jersey.
Amer. Jour. Sci., vol. 26, 1908, pp. 155-162.
Olivine-d diabase containing 15 to 20 per cent olivine occurs in a ledge 10 to 20 feet thick, which extends along the Palisades northward from Jersey City for 20 miles.
18. MERRILL, G. P. On the collection of Maine building stones in the U. S. National Museum.
Proc. U. S. Nat. Mus., vol. 6, 1883, pp. 176-177.
Brief description of olivine-d diabase quarried at Addison Point and Vinalhaven. Olivine frequently much altered to serpentine.
19. OSANN, A. Report on the rocks of Trans-Pecos, Texas.
Tex. Geol. Survey, 4th Ann. Rept., 1893, pp. 123-138.
Petrographic characters of an olivine-d diabase from the Diablo Mountains. Olivine is very fresh. Similar rock occurs in the Van Horn mountains.
20. PALACHE, C. Geology about Chichagof Cove, Stepovak Bay, with notes on Popof and Unga islands.
Harriman Alaska Exp., vol. 4, 1904, pp. 69-88.
Mentions a few "olivine-d diabase" dikes. No olivine present, but serpentine resulting from it.
21. POGUE, J. E. Geology and structure of the ancient volcanic rocks of Davidson County, North Carolina.
Amer. Jour. Sci., vol. 28, 1909, pp. 229-230.
Includes brief account of the olivine-d diabase here described in detail.
22. SHALER, N. S. Geology of Cape Ann.
U. S. Geol. Survey, 9th Ann. Rept., p. 609.
Olivine present in one dike.
23. SMITH, G. O. (*In* Analyses of rocks).
U. S. Geol. Survey, Bull. No. 168, 1900, p. 225.
Chemical analyses of olivine-d diabase from Kittitas County, Washington.
24. SMYTH, C. H., Jr. A group of diabase dikes among the Thousand Islands, St. Lawrence River.
Trans. N. Y. Acad. Sci., vol. 13, 1894, pp. 209-214.
"Olivine is an important constituent of a part of the dikes, is present in small amount in others, and is absent in about half."
25. VAN HISE, C. R., and BAYLEY, W. S. The Marquette iron-bearing district of Michigan.
U. S. Geol. Survey, Mon. 28, 1897.
Mentions the occurrence of fresh olivine-d diabase. No petrographic description.
26. WADSWORTH, M. E. Peridotytes, gabbros, diabases, and andesites of Minnesota.
Minn. Geol. Survey, Bull. No. 2.
Describes briefly many olivine-d diabases in which the olivine is more or less altered.
27. WATSON, T. L. The occurrence of nickel in Virginia.
Am. Inst. Min. Eng., Bull. No. 17, 1907, pp. 829-843.
Very brief description of dikes of olivine-d diabase in Floyd County.
28. ——— Weathering of diabase near Chatham, Virginia.
Am. Geol., vol. 22, 1898, p. 87.
Gives analyses of three olivine-d diabases, two of which are not fresh.
29. ——— Mineral resources of Virginia, pp. 36-37.
Includes summary of articles on olivine-d diabase in Virginia.

EXPLANATION OF PLATE 37.

- UPPER FIGURE. Olivine-diabase from Davidson County, North Carolina. A photomicrograph in ordinary light, magnified about 20 diameters. Section shows plagioclase laths, augite, and olivine; the last altering to talc. The ophitic texture is well illustrated.
- LOWER FIGURE. Olivine-diabase from Davidson County, North Carolina. A photomicrograph in polarized light, with crossed nicols, magnified about 20 diameters. Shows twinned plagioclase, augite, and grains of olivine.